MORPHOMETRIC CHARACTERISTICS OF THE PATELLAR TENDON

MORFOMETRIJSKE KARAKTERISTIKE LIGAMENTA ČAŠICE

Milodrag VRANJEŠIĆ1,2, Ivan VUKAŠINOVIĆ2, Mirko OBRADOVIĆ1,2, Mile BJELOBRK1, Zlatko BUDINSKI1 and Miroslav MILANKOV1,2

Summary

Introduction. The most common injuries of the knee joint are injuries of the anterior cruciate ligament. The golden standard in reconstruction of this ligament is graft bone–patellar tendon – bone. Knowing the morphometric characteristics of these ligaments is crucial for anterior cruciate ligament reconstruction. This study was aimed at determining morphometric characteristics of the patellar tendon in vivo, measured intraoperatively, and at defining the correlation between the obtained values and body weight, height, gender and sport activity among different groups of athletes. Material and Methods. This study included 184 patients suffering from anterior cruciate ligament injuries who were admitted to the Clinical Center of Vojvodina, Department of Orthopedics and Traumatology. Results. The patellar tendon width ranged from 28 mm to 43 mm, averaging at 32.02 mm. The length of the patellar tendon ranged from 35 mm to 62 mm, averaging at 46.34 mm. The thickness of the patellar tendon ranged from 3 mm to 6 mm, averaging at 3.78 mm. The measured results were positively and statistically relevant with the body mass, height and body mass index. Discussion and Conclusion. The patellar tendon was thicker, longer and wider in persons with higher values of body weight and height. Men have statistically longer, thicker and wider patellar tendon than women. There was no statistically significant difference between morphometric characteristics of the patellar tendon among professional athletes and recreational athletes, neither was there one in the obtained geometric data of the patellar tendon among tested groups of professional athletes.

Keywords: Patella; Patellar Ligament; Bone-Patellar Tendon-Bone Grafts; Morphological and Microscopic Findings; Athletes; Body Mass Index; Sex Factors; Body Weight; Body Height

Sažetak

Uvod. Povrede ligamenata kolenog zglobova su među najzastupljenijima u traumatologiji. Najčešće su povrede prednjeg ukrštenog ligamenta. Zlatni standard u rekonstrukciji ovog ligamenta predstavlja čašična veza sa svojim koštanim pripojima. Poznavanje morfometrijskih karakteristika ove veze je neophodno za adekvatno planiranje i izvođenje rekonstrukcije prednjeg ukrštenog ligamenta. Cilj istraživanja bio je utvrditi morfometrijske karakteristike in vivo ligamenta čašice, merene intraoperativno i utvrđivanje korelacije dobijenih vrednosti sa antropometrijskim merama, sportskom aktivnošću i među pojedinim grupama sportista. Materiaj i metode. Ispitivanu grupu činila su 184 pacijenta sa povredom prednjeg ukrštenog ligamenta, koji su hospitalizovani na Klinici za ortopedsku hirurgiju i traumatologiju Kliničkog centra Vojvodine. Rezultati. Širina ligamenta čašice bila je od 28 mm do 43 mm, dok je prosak 32,02 mm; dužina ligamenta čašice od 35 mm do 62 mm, prosečno 46,34 mm. Debljina ligamenta čašice bila je od 3 mm do 6 mm, prosečno 3,78 mm. Širina, dužina i debljina ligamenta čašice su pozitivno su i statistički značajno povezane sa telesnom masom, visinom i BMI. Diskusija i zaključak. Postoji statistički značajna povezanost između dimenzija ligamenta čašice i telesne težine, visine i pola. što osoba ima veću telesnu masu i visinu, to joj je ligament čašice deblji, duži i širi. Muškarci imaju značajno duži, deblji i širi ligament čašice od žena. Ne postoji statistički značajna razlika u morfometrijskim karakteristikama ligamenta čašice kod profesionalnih sportista i rekreativaca. Ne postoji statistički značajna razlika u izmerenim vrednostima dimenzija ligamenta čašice kod ispitivanih grupa profesionalnih sportista.

Ključne reči: patela; patelarna tetiva; BTB graftovi; morfološki i mikroskopski nalazi; sportisti; indeks telesne mase; polni faktori; telesna težina; telesna visina

Introduction

Ruptures of anterior cruciate ligament (ACL) are a significant epidemiological problem, especially because they usually occur to young people who are sport and work active [1]. The use of patellar tendon autografts for anterior cruciate ligament reconstruction is widespread and is considered to render good, reproducible clinical results [2]. The patellar tendon is the final connection of the extensor mechanism, connecting the inferior pole of the patella and the tibial tubercle. Technically, it is a ligament (connecting bone to bone), but it has historically been referred to as a tendon because the patella is a sesamoid bone. A bone-patellar tendon-bone (BTB) graft is the strongest of all biological substitutes; it achieves strong initial graft fixation using interference screws, allows bone-bone direct healing and offers rapid bony integration at the fixation points of the reconstruction [3, 4]. The disadvantage is graft–tunnel mismatch [5–9], a smaller cross-section area [10] and incompletely filling of the tunnel compared to the graft of the hamstring tendon [11–13]. The ACL has a “band-like” shape and does not have the same dimensions along its length [14]. The

Corresponding Author: Assist. dr Miodrag Vranješ, Klinički centar Vojvodine, Klinika za ortopedsku hirurgiju i traumatologiju, 21000 Novi Sad, Hajduk Veljkova 1-7, E-mail drivanvukasinovic@yahoo.com

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Clinical Center of Vojvodina, Novi Sad
Department of Orthopedic Surgery and Traumatology
University of Novi Sad, Faculty of Medicine

21000 Novi Sad, Hajduk Veljkova 1-7, E-mail drivanvukasinovic@yahoo.com
reconstructed ACL size is determined by the harvested graft size, not by the size of the native ACL insertion site [15–17]. It is important to know the geometric characteristics of the patellar tendon including the length, width, thickness, and cross-section area in order to determine the mechanical properties and achieve optimal ACL reconstruction.

The use of patellar tendon autografts for ACL reconstruction is widespread and the goal of this study was to determine morphometric characteristics of the patellar tendon (PL) in vivo, measured intraoperatively, and to define the correlation between the obtained values and the body weight, height, gender and sport activity among different groups of athletes.

**Material and Methods**

Having been given the permission by the Ethics Committee of Clinical Center a prospective study was conducted at the Department of Orthopedic Surgery and Traumatology. It included 184 patients with a torn ACL who agreed to participate in the study. The patellar tendon width, length and thickness were measured intraoperatively with a ruler.

Data were collected from the medical record, registry of patients operated at the Department of Orthopedic Surgery and Traumatology and ACL injury questionnaire. There were 154 men and 30 women (between the ages of 15 and 46 years), the average weight of the whole group was 80 kilograms (50-110 kilograms) and the average height was 181.26 cm (155-204 cm). The average body mass index (BMI) was 24.46 (from 17.72 to 32.77) (SD = 3.04). Half of the participants, i.e. 98 patients (53.3%) suffered an ACL injury while playing soccer and 25 of them (13.6%) when playing handball. According to the level of sports activity, all participants were graded to recreational athletes - 102 (55.4%), 77 (41.8%) were professional athletes and 5 were non-athletes (2.7%). The study excluded the patients already having a BTB graft, those who had an injury of the extensor mechanism of the knee (patellar fracture, rupture...
Anterior cruciate ligament injuries are injuries that are commonly found in athlete population. In Vojvodina, which has about two million people, about 400 reconstructions of the ACL (2 reconstructions per 10,000 residents) are performed per year. As for the European countries, the most accurate data are those from Denmark, where three injuries happen to every 10,000 residents per a year, the frequency of occurrence being higher among athletes [18]. These data are very similar to the data from the United States, where it is estimated that injuries occur in one out of every 3,000 people in the general population [19]. The reason for this epidemiological situation certainly lies in the fact that the number of participants in sports is constantly growing on the global level. Sports activities are becoming an important part of modern life and more and more people spend their free time in recreation and entertainment.

The group at the highest risk for ACL injury is young, sports active population. The male population prevailed in this study sample (83.7% men, 16.3% women), as in many other studies dealing with the same issue [1]. Women are at 2-10 times greater risk of ACL rupture in comparison to men, depending on the type of sport [20]. The reasons for epidemic appearance of ACL injuries among women in the world lie in the anatomic differences between genders, such as the size of Q angle, increased valgus of knee joint, narrow intercondylar notch, wider pelvis, impact of estrogen hormone on ligaments during menstruation cycle, general laxity of ligaments and different time of contractions between anterior and posterior groups of thigh muscles [1].

The average age of the patients included in this study was 25 years (15-46). Nearly half (46%) of the participants belonged to the age group between 21 and 30 years since the knee injury most commonly occurs in the third decade of life [21]. Body height, weight and body mass index were evaluated in several studies. Current views suggest that higher levels of body mass index may pose a potential risk factor for non-contact injuries. Kowalchuk et al. [22] in their study found that patients with a BMI ≥ 30 kg/m² had less successful results after ACL reconstruction than patients with a BMI in the normal range (BMI = 18.5-24.9 kg/m²).

In our study, BMI values of the participants were between 17.72 m/kg² and 32.77 m/kg². In the study Hashemi et al. [23] BMI was between 19.2 m/kg² and 44.4 m/kg². All the subjects in our study were from the territory of the Republic of Serbia and the height of the participants ranged between 155 and 204 cm (the average being 181.26 cm), as opposed to the study done by Hashemi et al. [23] which included data received from the Chinese people and they ranged from 152.4 to 182.8 (the average was 171.4 cm). These data correlate with the data from the literature stating that Europeans are generally higher than the Chinese people [24, 25].

The length of patellar tendon is observed as the distance from the top of the patella continued to the tibial tuberosity. Studies have shown the rate of BTB graft tunnel mismatch to be between 10 and 26% [6, 26, 27]. This occurs when the relative length of the bone-tendon-bone (BTB) construct exceeds the combined length of the intra-articular ACL distance and tibial tunnel length resulting in an intraoperative problem leading to extrusion or protrusion of the tibial plug graft and insecure tibial tunnel fixation with screw interference [28, 29]. According to Navali and, ACL reconstruction may be more problematic where the femoral tunnel is placed low on the lateral wall...
of the femoral notch, reducing the intra-articular graft length relative to non-anatomic vertical graft configurations. To accommodate the graft-tunnel mismatch and enable rigid fixation using interference screws, several methods have been proposed including: recession of the femoral bone plug [9], tibial tunnel bone grafting [30, 31], flipping the tibial bone plug [32, 33], graft twisting [5], changing the angle of drilling and drilling a longer tibial tunnel [8, 10]. The average length of the patellar tendon in our study was 46.34 mm (35–62 mm), and there was a significant correlation between the patellar tendon length and the patient’s gender. Denti et al. [7] measured the patellar tendon length intraoperatively and reported the mean patellar tendon length of 46 mm. In an intraoperative study done by Navali and Jafarabadi [30] the patellar tendon length was between 32–61 mm, which also showed a wide range of values. Shaffer et al. [6], who also measured the patellar tendon intraoperatively in 34 patients, and La Prade [34], who measured patellar tendon length in 50 cadavers, described the mean patellar tendon length of 48 mm (40–63). Although MC Alister et al. [35] recommended lateral radiographs to determine the patellar tendon length, MRI is the most frequently used method. The study Hashemi et al. [23] presented the average PL length of 50.93 mm and the studies that have measured the same value in the cadaver indicate lower values of the PL length [23, 36]. This can be explained by the assumption that ligaments are subject to dehydration in cadavers, thus their length is reduced. Yoo et al. [37] measured patellar tendons using MRI in 172 knees and reported the mean patellar tendon length of 46 mm. In an intraoperative study done by Tuncyurek et al. [39] showed that the average width of the patellar tendon was 4.5 mm and that PL length was 53 mm. Preoperative assessment of patellar tendon dimensionons, especially of the length and width of PL, is significant. Chang et al. [40] made the following mathematical equation to estimate the width based on the patient’s height: tendon width at middle portion (mm) = 0.202 × patient’s height (cm) – 5.07. Lairungruang at al. [41] compared the ultimate load bearing capabilities of the normal patellar tendon (4365.59 N) to the patellar tendon after its central third was removed (2226.58 N) and concluded that taking out the central third of the patellar tendon reduced both its cross-section area and ultimate load to one half.

The width and thickness of the harvested graft affect the cross-section area of the graft [42]. If a wider graft is harvested it can lead to a weakening of the remaining part of the tendon and its subsequent rupture [42, 43].

If a BTB graft has thickness of 3 mm, the width of 10 mm and the cross-section area (CSA) of 30 mm², it is still significantly less than the cross-section area of the native ACL and/or 8 mm diameter hamstring tendon graft (with 50 mm² of cross-section area) [43]. For the average thickness of the patellar tendon graft (3–5 mm) [29, 44] and 10 mm width, the CSA will be 30–50 mm².

The width of the patellar tendon is measured in the middle of the distance from the attachment on the patella to the tibia protuberance. A patellar tendon is wider proximally than distally because the fascicles tend to converge toward the midline [45, 46]. Yoo et al. [38] measured the width of proximal and distal part, and they found it to be 30 mm and 24 mm, respectively. The mean width of patellar tendon in the middle part in our patient was 33 mm (28–43).

The central third of the patellar tendon is significantly thicker than the medial and lateral thirds [44], and may be affected by long-term sports activity [47]. On the MRI [38, 48], cadaveric [44, 45] and in our study the average thickness of the patellar tendon was found to be between 3–5 mm.

The obtained value of the width of the patellar tendon was 32.04 mm on average (ranging from 28 to 43 mm), whereas in the study Lairungruang W. [42] the average width was significantly lower, 26.75 mm, as well as the results of the study Yoo et al. (30.3 mm) [38]. Andrikoula et al. [37] reported the average value of the width of the patellar tendon to be 31.9 mm whi-
which corresponds to our data. The patellar tendon width below 27 mm is a contraindication for the use of BTB autograft for ACL reconstruction. None of our participants had the patellar tendon under 28 mm in width.

According to the presented results, the patellar tendon length, width and thickness were significantly correlated with the dimensions of the body observed in our study (body weight, height and BMI). The correlation was the highest with the body height. There was also a statistically significant difference between the genders in favor of men for all parameters. These data are in contrast with the results of Wang [49] and Brown et al. [39] stating that the length of the ligament is not related to body weight, height and gender.

In relation to the level of the sports activities of the participants, slightly more than a half of them (56.4%) were recreational athletes, 41.8% were professional athletes, while 2.7% of participants identified themselves as non-athletes. The differences in the observed parameters of the patellar tendon and level of sporting activity have been obtained, but they were not statistically significant.

Depending on the type of sport that the participants went in for, there was the difference between the length, width and thickness of the patellar tendon, but this difference was not shown to be statistically significant except for the thickness of patellar tendon in football and handball, in favor of the football players (T test = 2.15, p <0.05). Those results can be explained by the fact that this examination included a low number of basketball players, only 19 of them, in relation to the 98 football players who participated in this study. Besides, the height of our participants was slightly below the average for the sport. Therefore, research on a larger sample might show a statistically significant difference in the dimensions of patellar tendon in different groups of athletes.

There are clearly some limitations to this study. The main limitation was the disproportionate percentage of men relative to women (83.7% men, 16.3% women). It should also be mentioned that women are less active in sport activities and consequently the number of their injuries of the ligaments relatively low. The second limitation is that the measuring with a ruler is subjectivity of the one who measures.

Conclusion

Knowing the morphometric characteristics of patellar tendon is crucial for anterior cruciate ligament reconstruction. The patellar tendon was thicker, longer and wider among persons with higher values of body weight and height. Men have the statistically longer, thicker and wider patellar tendon than women. There was no statistically significant difference between morphometric characteristics of the patellar tendon among professional athletes and recreational athletes, neither was there any between the obtained geometric data of the patellar tendon among tested groups of professional athletes (football, basketball, handball, rugby, skiing).

References


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